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Second Horizontal Derivatives of Ground Magnetic Data Applied to Gold Exploration in the Yilgarn Craton of Western Australia

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ABSTRACT

Ground magnetic surveys for gold exploration in the Archaean Yilgarn Craton of Western Australia are rapidly being replaced by low-level, high-resolution, fixed-wing and helicopter aeromagnetic surveys for detailed geological mapping of large areas. However, for exploration of areas that are either small, or where the buried magnetic sources are located near the surface, or where the magnetic response of the regolith is of interest, ground magnetic surveys are required in order to measure the high-frequency magnetic responses associated with these environments. Surface and subsurface geological features are often of interest when exploring for near-surface gold mineralisation.

Earlier work, by S. Mudge, has shown that bipole plots of second horizontal derivatives of aeromagnetic data are effective in resolving detail in aeromagnetic data. These have been applied to ungridded ground magnetic data and are effective in resolving high-frequency detail in the magnetic responses of subsurface rocks and the regolith. The large high-frequency component of ground magnetic data acquired from maghemite-rich regolith areas presents different and often difficult data processing and presentation problems compared with data acquired from higher-level aeromagnetic surveys. Despite this, second horizontal derivatives of ground magnetic data resolve important detail of magnetic subsurface rocks and the regolith that would otherwise be lost in images and contours of the gridded data.

For an area in the Kalgoorlie district of Western Australia, data from a ground magnetic survey and a low-level aeromagnetic survey were transformed with the second horizontal derivative filter to reveal different degrees of resolution of magnetic sources located in the regolith and the subsurface. Line profiles, and images and contours of the gridded data, from both surveys resolved subsurface sources which have assisted with the identification of drill targets. Importantly, however, magnetic features in the regolith were only resolved in the enhanced ground survey data which has assisted with geological mapping of the regolith.

Keywords: aeromagnetic data, bipole map, gold, ground magnetic data, horizontal derivative, maghemite, regolith, Yilgarn

INTRODUCTION

Low-level, high-resolution, fixed-wing aeromagnetic surveys are being used extensively to map bedrock and regolith geology in the Yilgarn Craton of Western Australia as part of gold exploration programs. There is a continual quest by explorers to acquire higher resolution data from aeromagnetic surveys. Ground magnetic surveys are often conducted where the area of interest is too small for airborne surveying, but they should also be used where the higher frequency magnetic responses of surface rocks are of interest.

Techniques designed to maximise the resolution of survey data, and to enable the interpreter to analyse large data sets in detail and in a timely manner, are of critical importance in exploration programs. To help achieve this goal, bipole plots of second horizontal derivatives of ground and airborne magnetic line data have been used in conjunction with images and contours of the gridded data for exploration of near-surface gold mineralisation.

Surface maghemite occurs widely in the Archaean Yilgarn Craton of Western Australia. It is often a source of high-amplitude noise in ground magnetic data and, consequently, limits the resolution of these surveys to mapping the magnetic responses of near-surface sources. However, the presence of maghemite can often allow the structure of the regolith and associated geology to be mapped using magnetic methods. The value of applying the second horizontal derivative filter to ground magnetic data compared with low level aeromagnetic data is demonstrated for a gold exploration area near Kalgoorlie, Western Australia.

APPLICATION OF SECOND HORIZONTAL DERIVATIVE

Mudge (1991) showed that bipole plots of the second horizontal derivative of ungridded aeromagnetic data are superior to images and contours of gridded data in resolving detail.

Bipole plots consist of a series of survey line profiles of red and blue coloured bar-graphs of the horizontal derivative. The polarity of the derivatives are changed so that the new positive values, which are characterised by red bar-graphs, coincide with anomalous magnetic sources. Blue bar-graphs depict negative derivative values and zero values appear as gaps in the bar-graph profiles. The horizontal derivative filter is applied to the flight-line data as a convolution filter.

The advantages of bipole plots of the second horizontal derivative are that the presentation is not distorted by spurious values interpolated between flight lines, particularly where levelling errors are present, and that small amplitude responses can be clearly recognised amongst neighbouring larger amplitude responses. However, the bipole maps will not resolve magnetic bodies that strike parallel to the survey lines. The most effective interpretation of survey data can be accomplished when contours and images of gridded data are complemented with second horizontal derivative bipole maps. Following the successful application of bipole maps to aeromagnetic data the method was applied to ground magnetic data to assist with detailed geological mapping of the subsurface rocks and the regolith.

It is well known that the amplitude of an anomaly decreases with increasing separation between the anomaly source and the instrument sensor. Ground and low-level airborne magnetic surveys are therefore appropriate for mapping magnetic sources buried near the surface and where mapping of the regolith is of interest. Maghemite-rich areas usually exhibit large amplitude, high frequency responses in ground magnetic data. Noise associated with the high frequencies is caused by under-sampling of the data along-line, survey location errors and instrument noise. These sources of error are related to the very steep gradients in the magnetic field caused by the highly magnetic near-surface maghemite. It is essential to attenuate this high-frequency noise before the data are transformed with the second horizontal derivative filter, otherwise important geological information can be masked by the derivative-enhanced noise.

COMPARISON OF DETAILED GROUND AND AIRBORNE MAGNETIC SURVEYS

Aeromagnetic and ground magnetic surveys were conducted in an area near Kalgoorlie Western Australia to map the subsurface geology. The ground survey was conducted with GSM-19 Overhauser proton precession total field magnetometers along parallel survey lines spaced 40 m apart and oriented 040°–220°. The data were sampled at intervals of 1metre along-line with the instrument sensor 2 m above the ground. The airborne survey utilised a cesium vapour sensor at a mean terrain clearance of 40 m along survey lines spaced 40 m apart and oriented 060°–240°. The along-line data interval was 7 m.

The ground magnetic data were filtered with a median filter of 41 equal filter weights and a low-pass averaging filter of 71 equal filter weights to attenuate very high-frequency noise. The data were then transformed to second horizontal derivatives and plotted as bipole maps. The aeromagnetic data were filtered with a low-pass averaging filter of 3 weights to attenuate instrument noise and processing round-off error. The dynamic range of the computed derivatives for both surveys was controlled by a square root function. The bipole map of the second horizontal derivative of the aeromagnetic data is shown in Figure 1 and that for the ground survey data is shown in Figure 2. An image of the gridded total magnetic intensity (TMI) ground survey data is shown in Figure 3. Note the

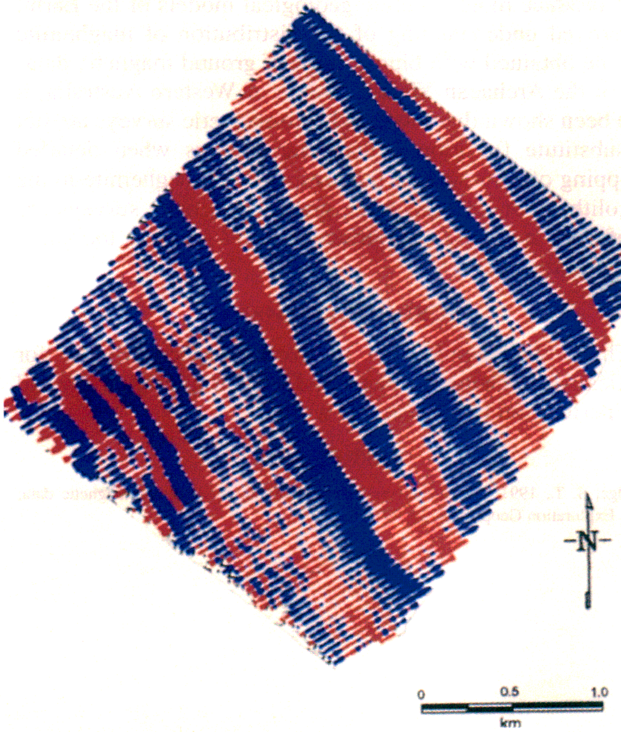

Figure 1. Bipole map of the square root of the second horizontal derivative of the aeromagnetic data.

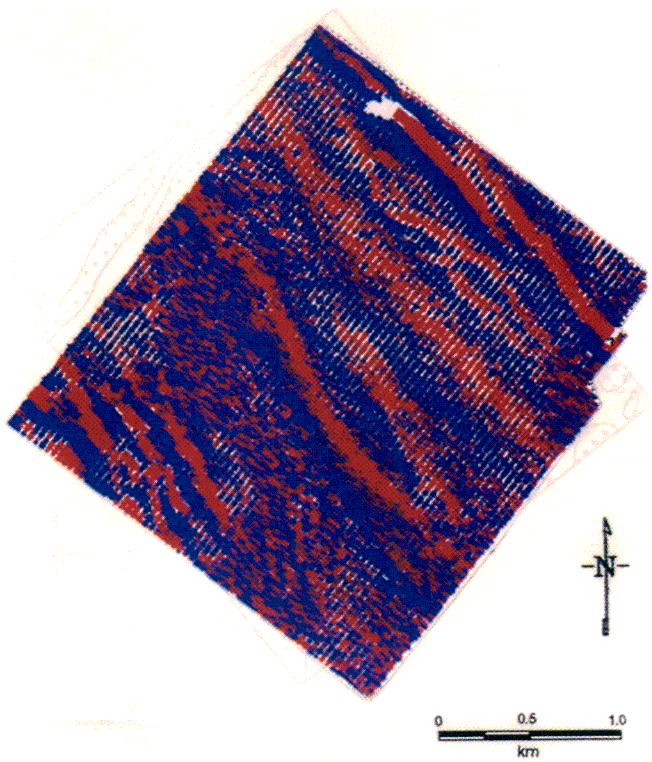

Figure 2. Bipole map of the square root of the second horizontal derivative of the ground magnetic data.

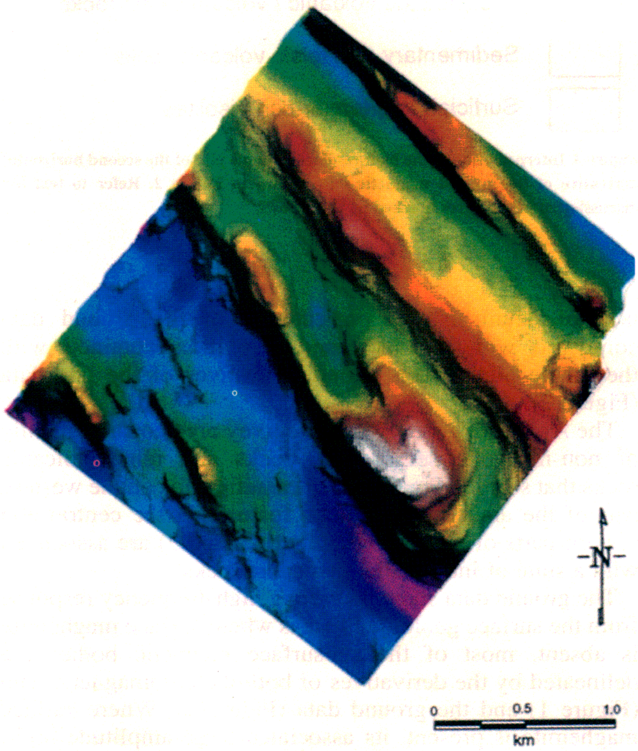

Figure 3. Image of total magnetic intensity of the ground data in grey scale, illuminated from the northeast and draped with pseudocolour of the total magnetic intensity.

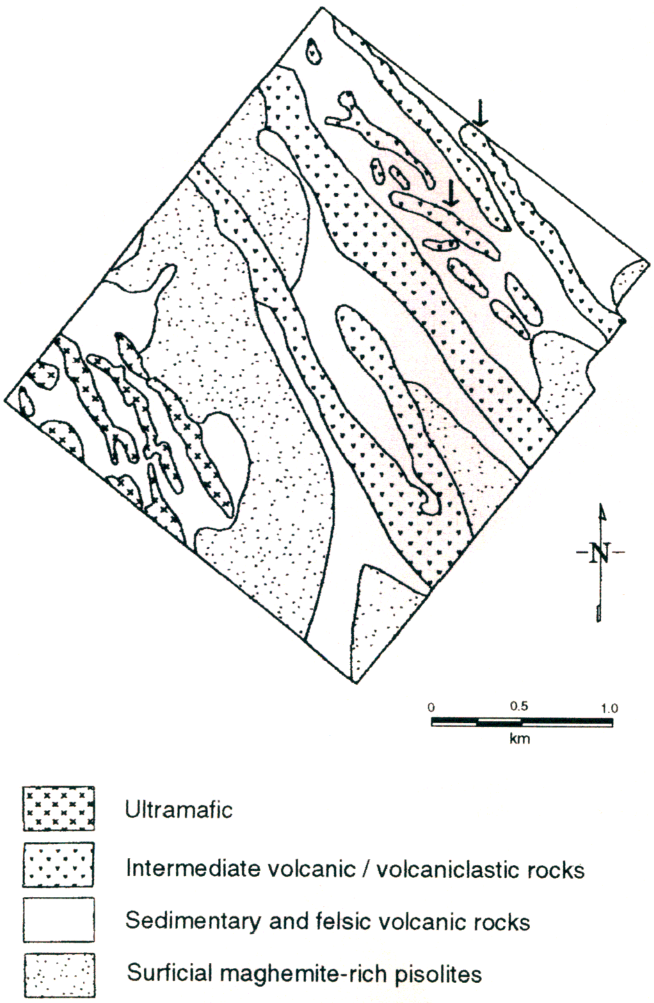

Figure 4. Interpretation of the high resolution bipole plot of the second horizontal derivative of the ground magnetic data shown in Figure 2. Refer to text for discussion of the features marked by the arrows.

lack of detail in this presentation of the ground data compared with the increased resolution obtained with the bipole plot of the second derivatives of the line data (Figure 2).

The Archaean geology of the survey area consists mainly of non-magnetic sedimentary rocks and felsic volcanic rocks that surround magnetic ultramafic units on the western part of the area. The magnetic features in the central and eastern parts of the area (Figures 1, 2 and 3) are associated with a suite of intermediate volcanic rocks.

The ground data show the strong high-frequency response from the surface geology. In areas where surface maghemite is absent, most of the subsurface magnetic bodies are delineated by the derivatives of both the aeromagnetic data (Figure 1) and the ground data (Figure 2). Where surface maghemite is present, its associated large-amplitude high-frequency response in the ground data obliterates the lower amplitude, longer wavelength response of subsurface sources and, consequently, limits the application of the second horizontal derivative of ground survey data to mapping the structure of the regolith (Figure 2).

The effect of upward continuation, as a result of the higher elevation of the airborne survey, can be seen in Figure 1. The high frequency response of the surface maghemite is attenuated by the airborne survey whereas it is very large in the ground survey data. The edges of the maghemite areas and the magnetic texture of the regolith are clearly delineated by the bipole map of the ground data (Figure 2), detail that is lost by the higher aeromagnetic survey.

The second horizontal derivative presentation of ground magnetic data is more effective at resolving shallow magnetic bodies and associated structures than presentations of gridded ground data. This can also be seen in the higher resolution of the two intermediate volcanic units on the eastern side of the area in the ground data (Figure 2) and indicated by the arrows in Figure 4. The image of the gridded TMI ground data does not resolve all individual units comprising the suite of intermediate volcanic rocks (Figure 3).

CONCLUSIONS

The second horizontal derivative filter applied to ground magnetic data from the Yilgarn Craton of Western Australia is effective in resolving detail of subsurface magnetic sources where no maghemite is present. The mapping of these geological features are of importance in the planning of exploratory drilling programs for near-surface gold mineralisation. Bipole maps of the second horizontal derivative are also particularly effective in delineating areas of surface maghemite and in resolving detail in the magnetic texture of the regolith that cannot be displayed in other formats.

Bipole maps of the second horizontal derivative are a valuable tool for the delineation of detail and complement images and contours of the gridded data. The combined use of these three forms of data presentation allow the interpreter to more thoroughly analyse magnetic survey data and produce more accurate geological models of the Earth. Improved understanding of the distribution of maghemite can be obtained with bipole maps of ground magnetic data.

For the Archaean Yilgarn Craton of Western Australia, it has been shown that low-level aeromagnetic surveys are not a substitute for ground magnetic surveys when detailed mapping of near-surface features, such as maghemite in the regolith, is of interest. Also, ground magnetic surveys are useful for mapping sub-surface features in areas too small for airborne surveys.

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REFERENCE

Mudge, S. T., 1991, New developments in resolving detail in aeromagnetic data: Exploration Geophysics **22**, 277-284.